4.2.2. DOBSON AND OZONESONDE MEASUREMENTS AT FAIRBANKS DURING TOMS^{3}F

TOMS^{3}F was a campaign to investigate the differences in total ozone measurements produced by ground-based and space-based instruments. The experiment was prompted by differences as high as 4% between values reported by Dobson or Brewer stations and the space-based TOMS, TOMS being higher. The difference is dependent on both total ozone and latitude. The campaign period of March and April 2001 coincides with high total ozone and low Sun, which appear to cause the differences. The experiment was funded primarily by NASA, and included CMDL, NASA, Meteorological Service of Canada (MSC), and University of Alaska, Fairbanks (UAF) instruments and personnel.

Dobson Measurements

The Dobson instrument and the method of operation are well documented [*Dobson*, 1931]. Briefly, the instrument measures the intensity differences of selected wavelength pairs (called A, C, and D) in the UV by attenuating the more intense wavelength to match the intensity of the other. If the atmospheric ozone absorption coefficients for those wavelengths and the instrument extraterrestrial constant are known, the total ozone amount can be calculated from the difference in the intensity between the two wavelengths of a pair either on direct sunlight or light from the zenith sky. Normally, measurements on two pairs are made to reduce the effects of other atmospheric constituents. Measurements using the A and D pairs on direct sunlight are considered the most accurate, and the results of other measurement types are normalized to the AD-pair type. Measurements using the C and D pairs on direct sunlight are used when the Sun is lower in the sky, i.e., higher solar zenith angles (SZAs). Measurements can also be made on the light scattered from the zenith sky, and ozone estimated from the results. If a series of measurements is made on the zenith sky as the Sun rises or sets (SZA changes from greater than 90º to 60º, or the reverse), the resultant time series of readings versus zenith angle has a characteristic shape that is related to the ozone distribution with height. This curve is called the Umkehr effect [*Götz*, 1931].

During the TOMS^{3}F campaign, measurements were made with both the normal Fairbanks station instrument, D063 (an automated instrument), and the World Standard Dobson instrument, D083. D083 made measurements in the period March 20-April 3, 2001; D063 made measurements throughout the campaign. This analysis concentrates on the period when both instruments were operational in Fairbanks, and stratospheric temperature data were available from the extensive balloon ozonesonde campaign. D083 made 453 observations, 139 of which were AD-pair type, 138 were CD-pair type, and the rest were various zenith measurements. D063 made 656 observations over a longer period, 161 of which were AD-pair type, 131 were CD-pair type, and the rest were various zenith observations. Figure 4.14 shows an overview of the total ozone measurements during the intensive measurement period. Eight measurements of the Umkehr effect were made with both instruments operating coincident with ozonesonde flights.

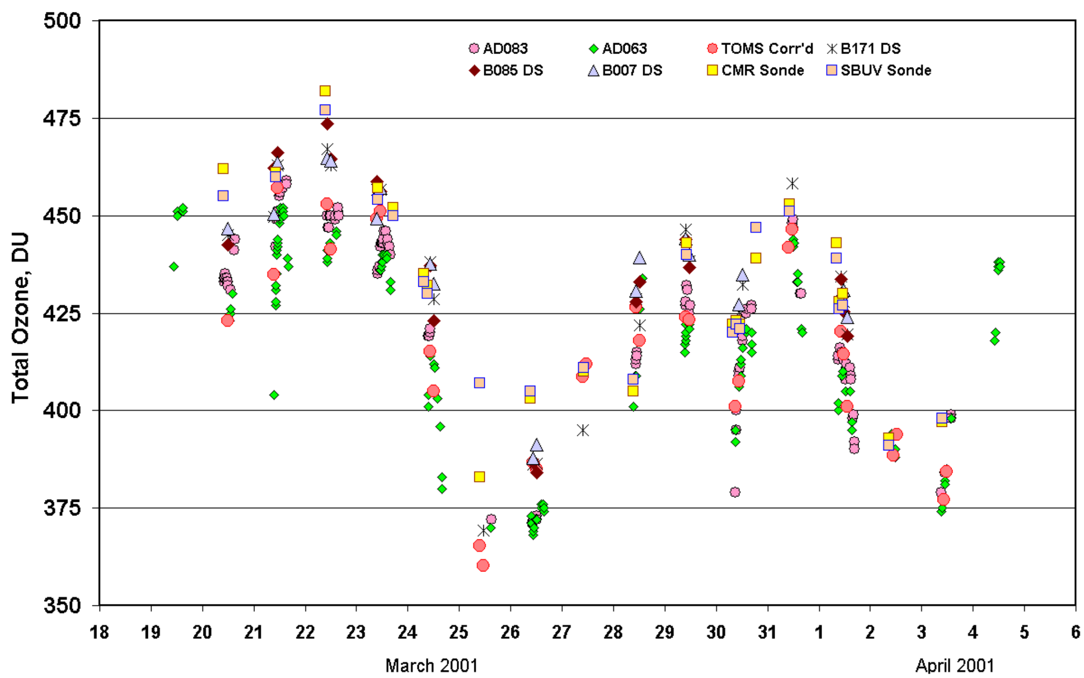

Fig. 4.14. Total ozone measurements at Fairbanks, Alaska, during the primary period of TOMS^{3}F. AD represents direct-Sun Dobson spectrophotometer observations from instruments D083 and D063; B are direct-Sun Brewer measurements; TOMS is the Total Ozone Mapping Spectrometer; and the ozonesonde totals are computed by the constant mixing ratio (CMR) residual method and by climatological averages based on solar backscatter ultraviolet (SBUV) satellite data.

The measurements were reduced using the published instrument characteristics and ozone absorption information, and both the normal algorithm, which uses ozone coefficients based on a standard midlatitude ozone profile assuming a −46.3°C stratosphere, and an algorithm from the actual stratospheric conditions measured by the balloon flights. The first discovery was a difference in the ozone calculated by the two instruments (AD-pair-type measurement), with D063 approximately 1-2% lower than D083 (Figure 4.15). An investigation of quasi-simultaneous measurements showed a calibration difference between the two instruments that accounts for the difference at lower SZAs but not at higher SZAs. The unexplained difference is related to μX, where μ is the optical path length of the direct solar beam through the most UV-light-absorbing part of the atmosphere, and is calculated from SZA. μ is dimensionless and varies from 1 at SZA = 0° to approximately 12 at SZA = 90°. X is the total column ozone amount in Dobson units. Both factors control the UV light intensity as seen by the instruments at the time of the measurement. Investigations by scientists at UAF showed that this μX dependence could be explained by scattered, off-band light within the instrument. (The instrument is a double prismatic monochromator. Multiple surfaces allow for multiple reflections, which produce both spurious spectra and scattered white light in the optical path.) Because the D083 instrument, as well as the D063 instrument, appeared to have some μX dependence, a double-grating monochromator Brewer 171 that has had the internal stray light measured independently was used as a reference. This Brewer instrument's measured stray light was found to be very low. Because an apparent lack of μX dependence of the CD-pair-type measurement in Figure 4.16 was noted as opposed to the μX dependence of the AD-pair in Figure 4.17, a model was derived to evaluate internally scattered light using only the relationship between the CD- and AD-pair-type observations (Figure 4.18). The physical alignment of several optical components during C-wavelength-pair measurements results in less scattered light in the optical path.

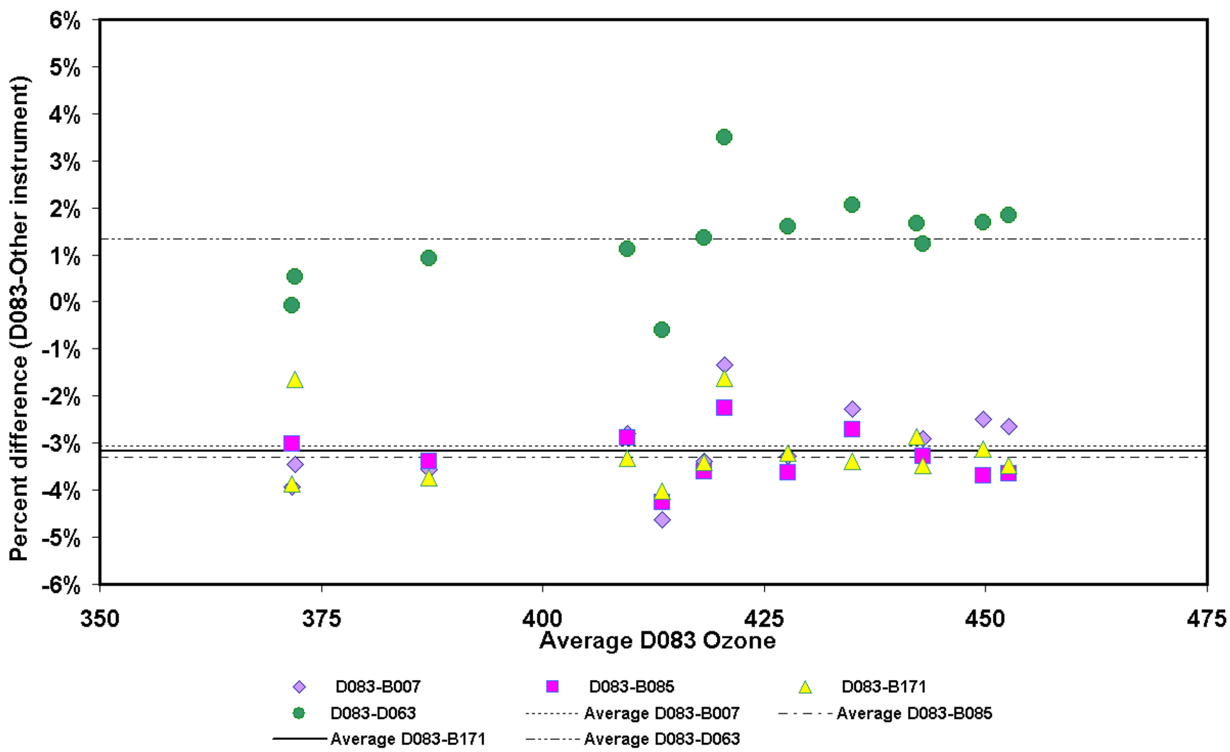

Fig. 4.15. Average percent difference between D083 (uncorrected for stratospheric temperature), and D063 (uncorrected) and the Brewer instruments, based on daily averages of direct-Sun observations, $\mu < 3.2$.

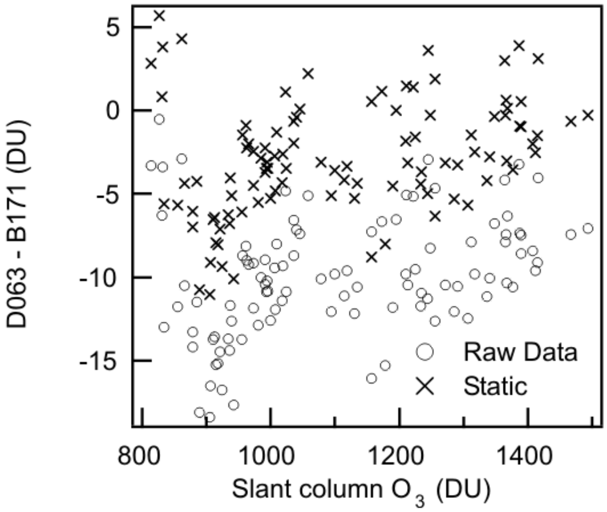

Fig. 4.16. The difference between D063 CD-pair direct-Sun ground quartz plate observations and B171 observations versus the slant column of ozone (μX). The open circles are the raw (reprocessed) Dobson data, and the crosses are the Dobson data corrected for the mean stratospheric temperature, known as the static correction.

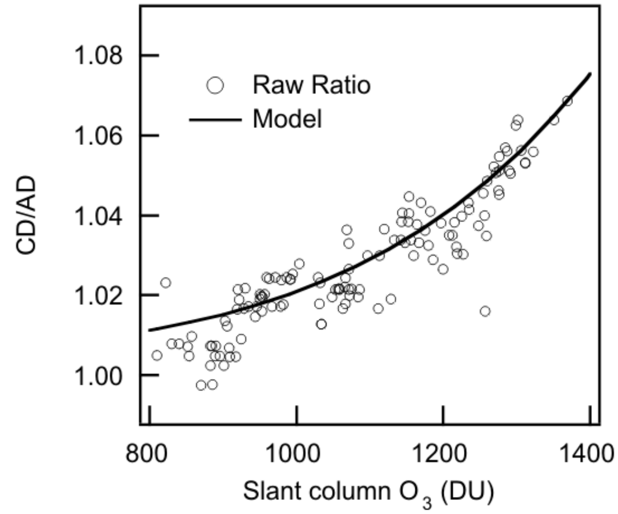

Fig. 4.18. The ratio between D063 CD-pair and AD-pair near-coincident observations plotted versus the slant column of ozone (μX). The open circles are the ratios for the raw (reprocessed) Dobson data, and the curve is from a model assuming 0.09% stray light on the Dobson A-pair observation, and no stray light on the C- or D-pair observations.

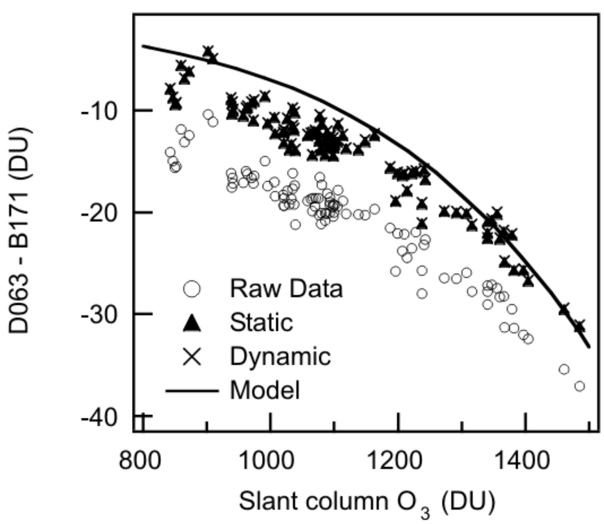

Fig. 4.17. The difference between D063 AD-pair direct-Sun ground quartz plate observations and the B171 observations versus the slant column of ozone (μX). The open circles are the raw (reprocessed) Dobson data, the filled triangles are the Dobson data corrected for mean stratospheric temperature, and the crosses are the Dobson data corrected for both stratospheric temperature and known absorption nonlinearity arising from finite slit widths. The solid curve is from a model that assumes 0.09% of the Dobson A-long light intensity is scattered into the Dobson A-short measured intensity.

Considering the difference between the instruments (μ range: 3.2 or less), the average is approximately 3% between the Brewer B171 results and Dobson D083 AD-pair results, with Brewer measurements higher (Figure 4.15) using the normal analysis method for Dobson measurements. After the analysis including the effect of the colder stratospheric temperature on the ozone absorption coefficients at the wavelengths used by the Dobson instrument, there remains an approximate 2% difference. The wavelengths used by the Brewer instrument have been shown to be independent of stratospheric temperature, and Dobson-Brewer intercomparisons at smaller μX (<900 DU) values and lower latitude sites with warmer stratospheric temperatures agree well. The difference at higher μX can be attributed to the effect of forward-scattered light in the atmosphere in the Dobson instruments' field of view, scattered light within the Dobson instruments, or a combination of the two.

Another conclusion of this campaign is that when selecting data, the μX factor would be a better criterion than the μ value. Making such a change in the selection process could have an effect on trend analysis at high latitudes, so the entire long-term data sets would have to be re-selected.

The Umkehr measurements with the C-wavelength pair produced very similar ozone profiles from both instruments, though the profiles differed from the balloon profiles. The differences can be attributed to the time difference between the measurements, the information content of the Umkehr measurement, and weaknesses in the reduction algorithm.

Ozonesonde Measurements

Thirty electrochemical concentration cell (ECC) ozonesonde instruments were flown during the TOMS³F campaign between March 20 and April 25, 2001. The ozonesondes provided vertical profiles of ozone concentration and an additional total column ozone measurement for comparison with the ground-based and satellite observations. The balloonborne instruments were launched from the University of Alaska, Fairbanks, every day, with several days of two to three balloon flights. Figure 4.14 shows that the ozonesondes measured slightly higher total ozone than the other methods, approximately 4.1% higher than Dobson instrument D083 and 2% higher than TOMS measurements. Figure 4.19 shows the average ozone partial pressure and mixing ratio measured during the campaign. The most variability in the profiles was observed near the ozone peak, as indicated by the standard deviation bars. The ozonesondes showed very good precision up to an altitude of 34 km.

The TOMS³F campaign was the first field project that used the EN-SCI Global Positioning System (GPS) interface board with ozonesondes. The ozonesondes used Vaisala RS80-N radiosondes to measure pressure, temperature, and relative humidity, while the GPS board collected latitude, longitude, and altitude data approximately every 5 seconds. The GPS altitude provided the location of the sonde, and thus winds, during the entire flight. The GPS altitude proved to be very beneficial in the correction of the calculated geopotential height from the Vaisala pressure and temperature data. Below 25 km the two altitudes compared very well, but above 25 km the difference (Vaisala geopotential – GPS altitude) was in the range from –200 m to +1000 m.